Automatic cracks detection in 3D µCT images using DVC total variation strain regularization

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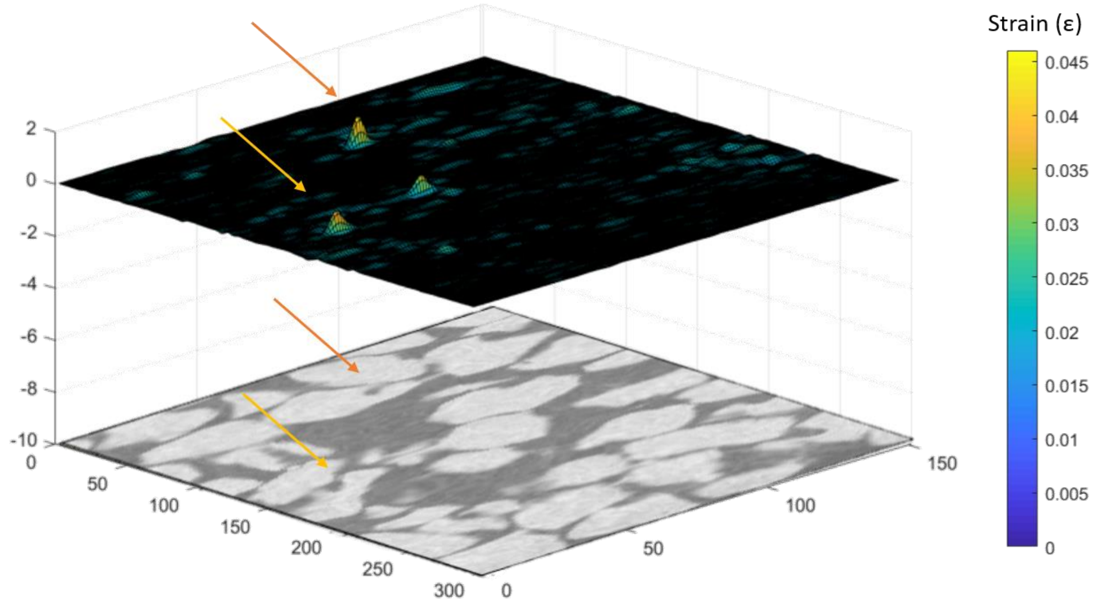
This work aims to automatically detect the location of cracks formation during uniaxial compaction experiment of grain assemblies using a robust and novel Digital Volume Correlation (DVC) approach. Experiments, such as absorption or compression, can lead to abrupt structural modifications of the material (e.g., swelling, tears or cracks), that demand robust algorithms to be detected and quantified. Over the years, many techniques have been developed for cracks detection and measurements. Some of them are based on variation of gray scale or color pixel intensities (direct measurements) [1], others are based on the results of Digital Volume Correlation (DIC) (indirect measurements) [2][3], most of these techniques are developed for 2D dataset. In many cases visual inspection is still in use [4].

DVC, based on the theory of DIC [5], but developed for 3D dataset, is a technique for displacement field measurements from which strain field is calculated. DVC is an ill-posed problem: multiple displacements can lead to a data-accurate and a good quality registration of images. Therefore, to distinguish realistic from unrealistic displacement, prior knowledge may be introduced in the form of a regularization term. In the case of grains aggregates the structure of the sample is heterogeneous and, therefore, it is plausible that during compression experiments each component of the sample has its own response in terms of strain (heterogeneous strain). Given the hypothesis of strain heterogeneity, the regularization term may be thought as a term that defines a piecewise constant strain penalizing the total variation (TV) of the strain. TV strain regularization method copes also with the presence of noise in the local strain field. Local strain is indeed computed based on the local variation of the displacement field (i.e., gradient of the displacement), therefore it is very sensitive to noisy small variations in the displacement field. Often the solution to this problem is the application of a smoothing filter [6] [7]. Filtering, in some cases, may be counterproductive: if on one hand it reduces the noise, on the other hand it reduces the resolution of the strain field and that is not a desired effect for cracks detection in µCt dataset [3].

Micro-CT dataset used in [8], obtained through the Yoda portal of Utrecht University, has been acquired during a compaction experiment on quartz assemblies at room temperature and dry condition. The compression has been performed at different loads (20 MPa- 25 MPa- 50Mpa). The first quartz grain breakage occurs at 20 MPa.

The method proposed in this paper can identify automatically, with high accuracy and high resolution, the location of the grains with cracks.



The picture shows the match between the peaks in the strain field and the cracks occurred in the quartz grains.

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